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Full Length Research Paper

Effects of soy-based allochthonous nutrient inputs on intensively cultured female *Clarias gariepinus* (Burchell) brooder's growth performance and on the in-dwelling net microplanktonic populations

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Portions of soybean meal autoclaved at 116°C and 1.2 kg/cm^2 pressure for 10, 15, 20, 25 and 30 min were used to compound 4 experimental diets appropriately labeled SB_{10}, SB_{15}, SB_{20}, SB_{25} and SB_{30} respectively. The experimental diets were fed to *Clarias gariepinus* female broodstocks intensively for 84 days. During the experimental period, the female fish broodstock growth performance as well as the water and the in-dwelling net microplanktonic quality were monitored. The feed inputs into the different culture media ranged between 13,759 g (SB_{15}) and 15, 649 g (SB_{10}). The highest weight gain was recorded in the female broodfish fed diet SB_{25}. The assayed water quality parameters for the different treatment culture media were not statistically different from each other (P > 0.05). Four (4) phytoplank-tonic phyla containing 7 orders with 30 species were recorded in the various media receiving the different feed inputs. The richest floristic composition with 21 species and a Margalef's Richness Index (R^1) of 1.66 was obtained in the culture medium that received SB_{25} feed input. Twenty (20) micro-invertebrate species belonging to 2 phyla and 4 orders were recorded in the various media during the period of study. The rotifers (Order: Ploima) with 16 species dominated the microinvertebrate fauna. Results also showed that the culture medium which received SB_{25} diet had the highest micro-invertebrate fauna with 19 species.

Key words: Soybean, feed input, *Clarias gariepinus*, water quality, microplankton.

INTRODUCTION

Clarias gariepinus which is a choice fish of culture in Nigeria requires adequate nutrition for fast growth and reproductive success (Adewumi, 2005). Culturing *C. gariepinus* broodstock intensively require continuous introduction of highly nutritious artificial feed into the culture system. Systematic addition of artificial feed and subsequent nutrient leaching from it as well as microbial decomposition of uneaten feeds and feacal matters pose a potential risk to water quality, the established biota and biological productivity (Bergheim and Asgard, 1996).

The leached nutrients and organic decompositions rich in nitrogen and phosphorus (Temporeti et al., 2000) subsequently play a fundamental role in the inherent biogeochemical dynamics of the aquatic ecosystems (Charrier et al., 2000). The ecologically relevance of the released nutrients is therefore contingent on their recycling or transfer to other compartments of the aquatic ecosystem (Beyruth and Tanaka, 2000). Inadequate nutrient compartmentalization or recycling however negatively impacts the water quality. Low survivability, poor growth rate and low reproductive potential are some of the reported sequential physical damage and nutrient enrichment induced intoxication effects on fish and other aquatic organisms (Barreto and Uieda, 2000). A major constraint in fish culture improvement in Nigeria is the provision of good quality feeds (Ezenwa, 1994). Balanced nutrition for fish broodstock enhances egg production, milt quality

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(FAO, 2000) and confer superior health and growth potential on the resultant progenies (Takeuchi et al., 1978). Fishmeal (imported wholly into Nigeria), is the choice protein source in compounded fish feed because it is rich in essential amino acids (Adewumi, 2005).

Most current fish nutrition studies are presently focused on the replacement and/or supplementation of scarce and expensive imported fishmeal component of the fish diet with alternative cheaper protein sources (Adewumi et al., 2005). Soybean meal is used as an economic sub-stitute for fishmeal in animal diets worldwide because of the rich quality of its amino acid profile, high digestibility (Lim and Akiyama, 1992) and ready availability (Adewumi et al., 2006). The use of soybean meal in fish feed pro-duction however, is limited by its deficiency in lysine and the presence of several anti-metabolites such as phytase and trypsin inhibitors (Khalifa et al., 1992). Protease inhibitors in raw or inadequately heated soybean meals adversely affect growth and reproductive performances in fishes (Peres et al., 2003). Adequate heat treatment of soybean meal is known to reduce the inherent trypsin inhibitory activity to a level where it supports optimal growth and reproductive efficiency in *C. gariepinus* (Adewumi et al., 2005).

The present study reports the effects of continuous and intensive feeding of soy-based diets to the *C. gariepinus* brooders growth performance as well as effects on water quality enrichment and planktonic community.

MATERIALS AND METHODS

Culture facility and the fish

The study was conducted in outdoor concrete tanks (6 x 5 x 1.5 m) filled with water from Obafemi Awolowo University Reservoir between May and August, 2005. *C. gariepinus* yearlings for the experiment (182 ± 10 g) were obtained from a commercial fish farm. Three hundred (300) healthy fish specimens were selected from the original stock of laboratory acclimatized 480 fishes and were distributed in batches of 30 into 10 labeled fine-meshed (0.752 mm) nylon hapas designated for the feeding trials. Water in the culture tanks were replenished periodically as the need arose to compensate for evaporation.

Experimental diet preparation

Portions of full-fatted, dried soybean seeds (SAMSOY 2 TGX 636-02D) winnowed, heat treated for different times (in an autoclave) and milled were used as the primary protein sources to compound experimental diets for *C. gariepinus* brooders (Adewumi, 2005). The soybean portions were autoclaved at 116°C and 1.2 kg/cm^2 presure for 10, 15, 20, 25 and 30 min respectively to remove the inherent trypsin inhibitors in the soybean meal (Peres et al., 2003) and to determine the appropriateness and adequacy of the various heating times used to remove trypsin inhibition. The differently autoclaved soybean portions were separately used along with other ingredients like: yellow maize, Tilapia fish meal and brewery waste (Adewumi, 2005) to compound approximately iso-nitrogenous (31% protein) and iso-caloric (3.34 kcalg^{-1}) experimental diets. The prepared diets were appropriately labeled SB_{10}, SB_{15}, SB_{20}, SB_{25} and SB_{30} (Table 1) to correspond with the different soybean heat processing times.

Ingredients for each experimental diet were properly mixed and extruded through an 8 mm diet using a Hobart A-200 mixer. The proximate compositions of the extruded pelleted experimental diets were determined according to AOAC (1990) while the gross energy contents were determined using Ackermann et al. (1969) method. Each of the diet was also wet-digested using perchloric acid and nitric acid mixtures (Diks and Allen, 1983) and the resultant digests were diluted using distilled water. The concentrations of Ca^{2+}, Mg^{2+}, Zn^{2+}, Cu^{2+} and Fe^{2+} in the diluted digest were then determined using atomic absorption spectroscopy (APHA et al., 1992). Phosphorus concentration in the digest was determined using molybdate-sulphuric acid reagent method (APHA et al., 1992).

Experimental feeding and data collection

The experiment which was primarily designed to determine adequacy of soybean toasting time on some growth parameters in *C. gariepinus* female brooders lasted for 84 days. During the experiment, the five prepared experimental diets (calculated on a dry matter basis) were fed twice daily at the allotted rate of 5% of the fish body weight. Each feed treatment was replicated. Feeding was accomplished by offering the prepared diet to the fish at the same spot between 08.00 - 09.00 G.M.T. and 18.00 - 19.00 G.M.T. Body weight changes in the fish were compensated for through weekly re-calculations of the rations offered to the experimental fish. Fish mortalities in the experimental tanks were monitored daily.

Data collection started on the first day of the feeding trials. Length (in cm) and weights (in gm) of individual fish stocked for each of the five dietary treatments were taken using standard techniques. Length-weight data collection repeated subsequently, weekly, was used to calculate the amount of feed offered, body weight changes and the condition factor. The gross feed input was determined according to Page and Andrews (1973) while the mean weight gained and the percentage body weight gained was obtained using Pitcher and Hart (1982) method. Estimation of the specific growth rate (SGR) was done according to Brown (1957) while Fulton's condition factor (K_f) indicating the state of fish well-being was calculated using the method of Le Cren (1951).

Water quality studies

Temperature, pH and conductivity of the water samples were determined in situ using a multi-probe HACH portable water laboratory daily. Duplicate sub-surface water samples collected fortnightly from each of the culture tanks using a Friedinger water sampler brought into the laboratory were analysed for the phenolphthalein acidity, carbonate alkalinity, phosphorus, nitrate and dissolved oxygen content (APHA et al., 1992). Na^+ and K^+ levels were determined flame photometrically (Golterman et al., 1978) while the Ca^{2+}, Mg^{2+}, Fe^{2+} concentrations in the water samples were read using Alpha 4, Model 4200, Chem Tech Analytical flameless atomic absorption spectrophotometer (AAS). The concentrations of PO_4^{2-} and NO_3^- were also determined according to Golterman et al. (1978).

Phytoplankton and microinvertebrate studies

Thirty (30) liters of water samples collected from each treatment tank fortnightly were filtered and concentrated to 20 ml using a 45 µ plankton net. The plankton concentrate samples were preserved in 5% formalin and two drops of Lugol solution for quantitative and qualitative examination. Planktonic identification and enumeration were done by introducing 1 ml of the preserved concentrate plankton samples into a Sedwick-Rafter counting chamber for examination through an Olympus BH2 Microscope. Planktonic identification

Table 1. Experimental diet formulations, the dietary energy content and the proximate composition of the experimental diets.

	Diets				
	SB_{10}	**SB_{15}**	**SB_{20}**	**SB_{25}**	**SB_{30}**
Formulation (g/100 g dry diet)					
Soybean	34.43	34.43	34.43	34.2	34.58
Fishmeal	3.34	3.34	3.34	3.57	3.19
Brewery wastes	37.78	37.78	37.78	37.78	37.78
Yellow maize	22.45	22.45	22.45	22.45	22.45
Mineral/Vitamins[1]	1.00	1.00	1.00	1.00	1.00
Vegetable oil	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00
Computations					
Crude Protein (%)	30.96	31.25	30.89	30.83	31.01
Dietary Energy (Kcal g^{-1})	3.46	3.37	3.86	3.93	3.06
Proximate composition (%) ($\overline{X}$ (SD))					
Crude protein	30.45 (3.12)	29.51 (0.88)	30.55 (1.42)	31.20 (2.18)	30.99 (2.51)
Moisture content	6.59 (0.08)	5.49 (0.06)	5.06 (0.96)	4.94 (1.88)	4.46 (0.59)
Lipid Content	4.02 (1.05)	4.65 (0.03)	4.68 (1.21)	4.81 (0.88)	3.82 (0.08)
Ash	6.81 (2.03)	7.22 (1.41)	7.41 (0.80)	7.85 (0.28)	9.33 (0.44)
Crude fibre	7.91 (0.09)	7.81 (1.02)	5.73 (0.09)	5.86 (0.28)	6.22 (0.55)
NFE[2]	44.22 (1.44)	45.32 (1.51)	45.90 (0.11)	46.34 (1.22)	45.18 (1.42)
Mineral Composition (mg/g) ($\overline{X}$ (SD))					
Iron	10.00 (2.31)	16.02 (1.19)	11.19 (2.11)	11.30 (2.19)	14.64 (1.19)
Copper	0.07 (0.01)	0.06 (0.01)	0.19 (0.01)	0.20 (0.10)	0.13 (0.01)
Magnesium	3.39 (1.08)	3.36 (1.02)	3.17 (1.08)	3.60 (1.21)	3.36 (1.08)
Calcium	62.98 (10.11)	72.96 (9.02)	66.36 (6.18)	76.36 (12.01)	73.02 (11.09)
Phosphorus	5.90 (1.25)	6.28 (1.15)	6.86 (1.20)	7.40 (2.01)	5.38 (1.91)

[1]Mineral inclusion (g Kg^{-1} dry diet): Manganese sulphate ($MnSO_4.4H_2O$) 0.0660, Iron sulphate ($Fe\ SO_4.7H_2O$) 0.3500, Copper sulphate ($CuSO_4$. $5H_2O$) 0.0290, Calcium iodate ($Ca\ IO_3.6H_2O$) 0.0112, Sodium chloride (NaCl) 1.1800, Potassium chloride (KCl) 0.0800, Calcium orthophosphate ($CaHPO_4$)2.550, Sodium selenite ($Na_2\ SeO_3$) 0.005, Vitamin inclusion (g Kg^{-1} dry diet): Vitamin A $9*10^6$, Vitamin $O_3 1.25*10^6$, Vitamin E $7*10^3$, Vitamin B_3 22, Vitamin B_5 14, Riboflavin 6, Choline chloride 240, Amino Acid inclusion (g Kg diet): Lysine 120, Methionine 65.

[2]NFE = Nitrogen-free Extract = 100 – (Crude protein + Crude fibre + Lipid content + Moisture content + Ash).

was done to specific levels according to Edmondson (1959), Adeniyi (1978) and Fernando (2002). Planktonic abundance, species richness, diversity and evenness were calculated according to Ludwig and Reynolds (1988).

Statistical analysis

Data collected were subjected to a non-parametric t-test (Mann-Whitney U-Nilcoxon Rank Sum W-test) for the comparison of means within treatments while the Kruskall-wallis one way ANOVA was used to compare means at 5% level of significance (SPSS statistical package programme, version 12.0)

RESULTS

Feed input and fish growth performance

The soybean-based feed inputs into the culture system ranged between 13,759 g (SB_{15}) and 15,649 g (SB_{10}) (Table 2) during the period of culture. The highest feed input into the culture medium per gram of fish flesh produced (1.88) was obtained in the culture medium that received SB_{10} feed, followed by the media receiving SB_{30} (1.70) and SB_{15} (1.69) feeds respectively. The lowest value (1.31) was obtained in the culture medium that received SB_{25} feed.

The growth performance of *C. gariepinus* female broodstock fed the soybean-based diets showed that the highest growth rate was obtained in the broodfish fed SB_{25} diet closely followed by the fish fed SB_{20} diet. Also, the percentage weight gained by the female broodfish fed SB_{20} and SB_{25} diets were significantly higher ($P < 0.5$) than those of the fish fed other soybean-based diets. The specific growth rate (SGR) of the female broodstocks in the different culture media varied between 0.22 ± 0.05

Table 2. Growth performance[1] of *C. gariepinus* female broodstocks during the period of study.

	Dietary Treatments				
	SB_{10}	SB_{15}	SB_{20}	SB_{25}	SB_{30}
Initial Weight (g)	207±10^{ab}	182 ± 18^{b}	192 ± 28^{ab}	198 ± 9^{a}	206 ± 23^{ab}
Final Weight (g)	277±54^{b}	272 ± 65^{ab}	359 ± 73^{a}	379 ± 63^{a}	304 ± 82^{b}
Percentage body weight gained (%)	34.05^{a}	49.56^{b}	86.90^{c}	91.38^{c}	47.20^{b}
Specific Growth Rate	0.22±0.05^{a}	0.26 ± 0.05^{ab}	0.32 ± 0.16^{b}	0.34 ± 0.03^{b}	0.25 ± 0.05^{a}
Fulton's Condition Factor (kf)	0.82±0.25^{a}	1.02 ± 0.32^{a}	1.02 ± 0.26^{a}	1.11 ± 0.34^{a}	0.89 ± 0.22^{a}
Survival Rate (%)	100.0	98.0	100.0	100.0	100.0
Gross Feed Input (g)	15,649^{a}	13,759^{b}	14,515^{c}	14,968^{c}	15,573^{a}
Feed Input/g body weight gained	1.88^{a}	1.69^{b}	1.35^{c}	1.31^{c}	1.70^{b}

[1]Values with the same superscript in each row are not significantly different (P > 0.05) from each other.

Table 3. Water quality parameters* of the culture media receiving different soybean-based feed input

	Dietary Treatments				
Parameters	SB_{10}	SB_{15}	SB_{20}	SB_{25}	SB_{30}
Physico chemistry					
Temperature (°C)	28.75±0.97	28.88±0.83	28.50±0.87	28.38±0.92	28.88±0.85
pH	7.96±0.27	8.20±0.33	8.10±0.18	8.10±0.17	8.11±0.22
Total Alkalinity (mg/l)	141.89±15.45	179.25±1.30	172.52±15.27	173.63±16.08	174.75±14.13
Phenophtatein Acidity (mg/l)	21.67±4.67	28.33±7.26	28.23±6.01	25.33±9.84	19.17±3.00
Conductivity (µs/cm)	32.30±1.02	36.43±1.00	33.63±0.56	34.88±2.14	34.25±0.33
Dissolved oxygen (mg/l)	3.76±1.02	5.20±2.31	3.93±1.65	2.70±1.82	4.43±1.65
Ions (mg/l)					
Na^{+}	7.98±1.82	8.42±2.33	8.24±2.04	8.95±2.26	8.28±2.47
K^{+}	48.56±18.11	50.60±12.96	47.40±13.92	51.10±19.39	49.27±18.05
Ca^{2+}	29.05±6.37	31.35±4.44	31.03±7.43	43.05±17.53	42.97±20.27
Mg^{2+}	0.67±0.12	0.70±0.21	0.68±0.14	0.66±0.10	0.59±0.13
Fe^{2+}	3.45±1.81	5.91±1.09	2.25±0.85	2.91±1.09	1.60±0.65
PO_4^{2-}	13.06 ±1.00	18.36 ±0.78	12.79±3.28	18.37±3.44	18.65±1.43
NO_3^{-}	21.85 ±0.93	20.17±4.55	20.53±9.08	17.53±1.76	24.84±5.18

*Parameters not significantly different from each other (P > 0.05).

(SB_{10}) and 0.34 ± 0.03 (SB_{25}. Although variations occurred in the condition factor of the broodfish in the various culture media, the recorded differences were not significantly different (P > 0.05) from each other (Table 2).

Water quality

Analyses of the quality of water receiving the different dietary feed inputs shown in Table 3 revealed that the levels of the assayed parameters varied within a narrow amplitude of concentrations which were not statistically different from each other (P > 0.05). Irrespective of the quality of the dietary nutrient input, the culture water was alkaline with a mean pH value ranging between 7.96 (SB_{10}) and 8.20 (SB_{15}) with a mean total alkalinity value of between 141.89 mg/l (SB_{10}) and 179.25 mg/l (SB_{15}).

Potassium (K^{+}) was the dominant ion in the culture media, with concentration ranging between 47.40 mg/l (SB_{20}) and 50.60 mg/l (SB_{15}). Ca^{2+} with concentrations varying between 29.05 mg/l (SB_{10}) and 43.05 mg/l (SB_{25}) also had relatively high concentration in the water of the various culture media. The recorded levels of NO_3^{-} in the culture media ranged between 17.53 mg/l (SB_{25}) and 24.84 mg/l (SB_{30}) whole the concentrations of PO_4^{2-} ranged between 12.79 mg/l (SB_{20}) and 18.65 mg/l (SB_{30}).

Phytoplanktonic composition

Four (4) phytoplanktonic phyla containing 7 orders with 30 species were recorded in the culture media receiving the differently toasted soybean-based feed inputs (Table 4). Irrespective of the type of feed input, the dominant cyanophyte in the culture media was Anacystis incerta (Order: Chroococcales). Gomphosphaeria wichurae

Table 4. Phytoplanktonic and abundance composition (individuals /m^3) of the culture media receiving different soybean-based feed inputs.

	Dietary Treatments				
	SB_{10}	**SB_{15}**	**SB_{20}**	**SB_{25}**	**SB_{30}**
CYANOPHYTA					
Order: Chroococcales					
Anabacena variabilis Kütz	-	-	-	17	-
Anacystis incerta Lemm.z	17275	78999	31133	44583	24216
Gomphosphaeria wichurae (Hilse)	6990	31125	66	8	3400
Merismopedia sp.	6900	8	10375	27500	-
CHLOROPHYTA					
Order: Volvocales					
Eudorina elegans (Ehren)	-	-	-	66	-
Palmella miniata (Leibl)	83	91	182	-	91
Sphaerocystis schroeteri (Chodat.)	51550	33	44724	27616	55,000
Order: Chlorococcales					
Chlosteriopis longissima (Lemm.)	58	6974	157	6957	83
Pediastrum biradiatum (Meyen)	281	338	124	17300	248
Scenedesmus denticulatus (Lager.)	437	10466	198	361	17721
Schroederia setigera (Lemm.)	34508	-	-	17	-
Tetraedron regulare (Kütz)	8	-	33	66	-
Treubaria crassispina Smith	-	-	33	-	-
Order: Ulotrichales					
Draparnaldia pulmosa vaucher	8	-	-	-	-
Stigeoclonium lubricum (Dillw.)	8	-	-	-	-
Ulothrix zonata (Web et Mohr)	-	17	-	42	-
Closterium acerosum (Shrank)	-	-	-	8	-
Closterium leibleini (Kütz)	-	-	-	8	-
Micrasterias radiata (Hass)	17	25	17	50	8
Mougeotia transedui (Collias)	-	-	33	-	-
Staurastrum arbiculare (Ralfs)	10449	8	8	6950	83
EUGLENOPHYTA					
Order: Euglenales					
Euglena acus (Ehren).	-	-	-	-	8
Trachelomonas volvocina *Ehren.*	107	99	99	8	33
CHRYSOPHYTA					
Order: Peridinnales					
Ceratium hirundinella *Schrank*	-	10	-	-	6
Order: Bacillariales					
Asterionella Formosa *Hass.*	-	17	-	-	-
Biddulphia laevis *Ehren.*	-	8	-	-	-
Navicula radiosa *Kütz*	41	83	190	74	13,800
Nitzschia sigmoidea *(Nitz.)*	8	25	16	17	215
Synedra ulna *(Nitz.) Ehren.*	31125	34550	34548	17416	20816
Species Richness (R)	19	18	19	21	15

(Order: Chroococcales) was abundant in the culture media that received SB_{10}, SB_{15} and SB_{30} experimental feeds while Merismopedia sp. was an important blue green alga in the culture media receiving SB_{10}, SB_{20} and SB_{25} feed inputs.

Sphaerocystis schroeteri (Order: Volvocales) dominated the chlorophyte in most culture media. Other important green algae recorded in the different culture media belonging to the Order Chlorococcales include: Pediastrum biradiatum (SB_{25}); Scenedesmus denticulatus (SB_{15} and

Table 5. Microinvertebrate composition and abundance (individuals /m^3) of the culture media receiving different soybean-based feed inputs.

	Dietary Treatments				
	SB_{10}	**SB_{15}**	**SB_{20}**	**SB_{25}**	**SB_{30}**
ROTIFERA					
Order: Ploima					
Albertia typhilina Harr. and Myers	25	83	-	74	25
Anuraeopsis racenesis Lauter.	272	91	91	41	25
Argonotholca foliacea Ehren.	-	-	-	8	-
Asplanchna priodonta Goose	511	41	74	108	41
Brachionus angularis Goose	58	25	10565	7271	7372
Brachionus calyciflorus Pallas	25	223	231	314	33
Brachionus falcatus Zach.	10375	107	-	8	8
Brachionus rubens Hud. and Goose	305	1746	173	132	10573
Euchlanis dilatata Ehren.	-	-	-	-	-
Keratella cochlearis Goose	8	-	58	75	33
Lecane (*Lecane*) *luna* Muller	272	303	8311	7065	800
Lecane (*Monostyla*) *bulla* Goose	-	124	116	99	124
Lepadella patella Muller	8	-	17	-	17
Polyarthra vulgaris Ehren.	388	17	363	140	-
Trichocerca bicristata Goose	173	50	3945	248	545
Trichocerca rutterni Donner	17	8	1020	107	8
ARTHROPODA					
Order: Copepoda					
Cyclops scutifer Sars	421	17	157	215	124
Order: Cladocera					
Daphnia magna Straus	10466	116	25	17	421
Nauplius larvae	4011	91	710	436	347
Order: Diptera					
Chironomid larvae	148	24	35	49	60
Species Richness (R)	17	16	16	19	17

SB_{30}); Schroederia setigera (SB_{10}) and Staurastrum arbi-culare (Order: Ulotrichales) (SB_{10} and SB_{25}). The domi-nant diatom species in the various culture media was Synedra ulna (Order: Bacillariales), while Navicula radio-sa was abundant in the culture medium receiving the SB_{30} feed input.

The culture medium receiving SB_{25} feed input had the richest floristic composition with 21 species and a Margalef's Richness index (R^1) of 1.66. The poorest phytoplanktonic assemblages (15 species) occurred in the culture medium receiving SB_{30} feed input. The poor species richness recorded also reflected in the calculated Margalef's Index (1.17) obtained (Table 5). The Simpson's Index of diversity (λ) for the phytoplanktonic assemblages in the culture media ranged between 0.16 (SB_{25}) and 0.20 (SB_{15}). The values obtained in the calculation of the Simpson's Index (known to be inversely proportional to diversity) revealed the dominance of a few species in the culture media receiving SB_{15} and SB_{30} feed inputs respectively.

The highest number of phytoplanktonic individuals per cubic meter of water (180,628 ind/m^3) was recorded in the experimental culture medium receiving SB_{10} feed input closely followed by the culture medium that received SB_{15} feed inputs (173,365 ind/m^3). The least number of phytoplanktonic individuals (129,084 ind/m^3) was recorded in the culture medium receiving SB_{20} feed inputs (Table 4). Deductions from Hill's second diversity number (N_2) showed that the number of phytoplanktonic species which accounted for the abundance in the various experimental culture media vary (Table 6). In the culture media receiving SB_{10} and SB_{15} feed inputs, 6 and 4 species accounted for 92 and 90% of the recorded abun-dance respectively. For the culture medium receiving SB_{25} feed inputs, only 7 algal species accounted for 91% of the abundance compared to 5 species being responsible for 86% of the abundance in the culture medium receiving SB_{30} feed inputs. The results also showed that 6 phytoplanktonic species accounted for 94% of the abundance in the culture medium that received SB_{20} feed input. The Hill's Evenness indices (E4 and E5) (Table 6) confirmed the dominance of few abundant phytoplanktonic species

Table 6. The planktonic richness, diversity and evenness of the culture media receiving different soybased nutrient inputs.

Indices	Dietary Treatments				
	SB_{10}	SB_{15}	SB_{20}	SB_{25}	SB_{30}
Phytoplankton richness					
Margalef (R^1)	1.49	1.41	1.53	1.66	1.17
Diversity Indices					
Simpson (λ)	0.18	0.29	0.26	0.16	0.20
Hill's Second Diversity Number (N_2)	6.67	3.47	3.86	6.22	4.91
Abundance (%)	92.0	90.0	94.0	91.0	86.0
Evenness Indices					
Hill (E_4)	0.83	0.78	0.88	0.88	0.84
Modified Hill (E5)	0.79	0.72	0.84	0.86	0.80
Zoo invertebrates richness					
Margalef (R^1)	1.57	1.47	1.48	1.86	1.61
Diversity Indices					
Simpson (λ)	0.31	0.35	0.30	0.38	0.40
Hill's Second Diversity Number (N_2)	3.23	2.88	3.39	2.61	2.52
Abundance (%)	90.4	74.1	92.1	89.9	91.2
Evenness Indices					
Hill (E_4)	0.76	0.53	0.75	0.72	0.74
Modified Hill (E5)	0.68	0.42	0.68	0.61	0.64

in the different culture media.

Microinvertebrate composition

Twenty (20) microinvertebrate species belonging to 4 orders and 2 phyla were recorded in the various media receiving soybean-based nutrient inputs (Table 5). Analyses showed that the lowest number of species (16 species) was recorded in the culture media receiving SB_{15} and SB_{20} feeds while the culture medium receiving SB_{25} feed had the highest microinvertebrate faunae of the culture media were dominated by the rotifers (Order: Ploima). In all, 16 rotifer species were recorded compared to 4 species of arthropods. The microinvertebrate population of the culture medium receiving SB_{10} feed input was dominated by Brachionus falcatus (Rotifera) and Daphnia magna (Arthropoda). B. rubens (Rotifera) dominated the culture medium receiving SB_{15} feed input while B. angularis (Rotifera) dominated the culture media receiving SB_{20} and SB_{25} feed inputs respectively. In the culture medium receiving SB_{30} feed input, B. angularis and B. rubens were the dominant rotifers (Table 5).

Margalef index of diversity (R^1) (Table 6) which ranged between 1.47 (SB_{15}) and 1.86 (SB_{25}) also reflected the micro-invertebrates faunistic richness in the media receiving the different soybean-based feeds. The Simpson's diversity index (λ) for the microinvertebrates in the different culture media which ranged between 0.30 (SB_{20}) and 0.40 (SB_{30}) probably indicated the dominance of a few species. The culture medium receiving SB_{10} feed had the highest number of microinvertebrate individuals (27, 483 ind/m^3) closely followed by the culture media receiving SB_{20} feed (25,891 ind/m^3) and SB_{30} feed (20,556 ind/m^3) (Table 5). The calculated Hill's second diversity number (N_2) showed that 3 species accounted for 90.4% of the microinvertebrate faunal abundance in the culture me-dium receiving SB_{10} feed input compared to 4 species which accounted for 91.2% of the faunistic abundance in the culture medium receiving SB_{30} feed input. Analyses further showed that 3 species accounted for 89.9% and 74.1% of the microinvertebrates in the culture media re-ceiving SB_{25} and SB_{15} soybean-based feed inputs respectively (Table 6). The analyses also showed that the abundance of the species in the various culture media receiving feed inputs relatively diverge away from even-ness.

DISCUSSION

Significantly higher growth performances exhibited by female *C. gariepinus* broodfish fed SB_{25} and SB_{20} diets (compared to other experimental diets) indicated obvious differences in the nutrient composition of the experimenttal diet (Keembiyehetty and Gatlin, 1997; Adewumi, 2005). Heat treatment is known to deactivate trypsin inhibitory activity to varying degrees in soybean meal (Fournier et al., 2004). Anti-nutritional factors which were not deactivated completely in diets compounded from low-heated soybean-meals probably impaired the absorption of the needed essential amino acids needed for new protein formation in the fish (De Francesco et al., 2004). Conversely, adequate toasting of soybean meal component of the diets probably lowered the trypsin inhibitory activities (Savage, 1989) resulting in higher protein utilization in the fish (Peres et al. 2003) which subsequently translated significantly to the weight gained recorded (Adewumi, 2005). Fish fed the long-heated soybean-based diet (SB_{30}) showed relatively low growth, as indicated by low weights of individuals fed the diet. Longer heating of soybean meal probably resulted in denaturation of heat labile essential amino acids and formation of indigestible protein-carbohydrate complexes with consequential reduction in the availability of the essential lysine and arginine (Renitz, 1984). The high condition factor recorded in the *C. gariepinus* broodfish culture in all the treatments might have resulted from the weight of maturing ovary (De Silva and Anderson, 1998) which was high during the period of study.

The characteristics of water in the different culture media showed positive chemical and biological sensitivities to impactment from the different soybean-based diets (Elliot et al., 2006). The soybean toasting time which influenced the nutrient composition of the various diets probably directly dictate the type and concentration of nutrients leached from uneaten feeds and faecal matter into the culture medium. Secondarily, the bacteria mineralization in the uneaten food and faecal matters is expec-ted to add to the nutrient load of the various culture media (Van De Bund et al., 2004). Relatively high amount of PO_4 and NO_3 recorded in the culture media during the period of study probably disproportionately affected phytoplankton composition and productivity (Steiner et al., 2005; Van Ruijven and Berendse, 2005). Such increment in algal biomass and productivity with nu-trient enrichment has been reported by Smith (2003). Variability of the nutrient types in the different culture me-dia also affected the phytoplankton biodiversity (Dodson et al., 2000) and the phenology of the dominant taxa (Elliot et al., 2006). The phytoplankton biomass was largely dominated by many blooming species which include: *A. incerta, S. schroeteri,* Spirogyra varians, S. ulna, P. biradiatum and S. setigera (Loreau, 2000).

Variations which occur in the phytoplankton community structure of the media receiving the different diets was probably be due to species specific differences in nutrient use (Loreau, 2000; Cardinale et al., 2002). Complementary nutrient use which occurs when species do not exhibit complete overlap in nutrient use (Cardinal et al., 2004) probably accounted for the dominance of different phytoplankton species in the various media receiving the differently treated soybean-based diets. The zooplankton community structure was probably regulated by the phytoplankton quantity and quality (Qin and Culver, 1996). Zooplankton species composition and diversity is known to be dependent on the efficiency of zooplanktonic herbivory on the phytoplanktons (Sommer et al., 2001; Van Ruijeven and Berendse, 2005; Romanuk et al., 2006). The study showed that compounding fish diets with adequately heat-treated soybean meal (20 – 25 min) produced female broodfish with higher mean weight gained. Conversely, low heat treatment of the soybean component of the fish diet produced fish with relatively low weights. Higher levels of trypsin inhibitory activities in the low-heated soyabean-based diets caused growth depression in the fish due to reduced nutrient availability (Peres et al., 2003). Overheating (30 min) of the soyabean component of the female fish brooder's diet which resulted in denaturation of some essential amino acids as well as complexing of others with the carbohydrate components (Renitz, 1984) also led to low weight gained in the fish. Desirable water quality parameters during the period of study were probably responsible for the low fish mortality recorded. The planktonic quantity and quality were dependent on the nutrient availability in the treatment tanks because other environmental parameters were homogenous during the period of study.

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